BULLETIN 550 JULY, 1935

Sugar, Acidity, and Juice Color Determinations in Grapes

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OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

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J. S. SHOEMAKER

INTRODUCTION

The sugar content, acidity, and color of untreated juice of 120 grape varieties growing in the vineyard at Wooster, Ohio, were determined in 1933 and 1934. Information on sugar, acidity, and juice color of grapes is useful from a number of standpoints.

The quality or flavor of varieties commonly is expressed as "good", "fair", or "poor", is based entirely on taste, and is a matter of opinion. However, tastes differ. One person may prefer the flavor of a certain variety; whereas another person may not find it agreeable. Flavor depends, in part, on the amounts and proportion of sugar and acid. In general, grapes with a high sugar content are "sweet". However, grapes with a high sugar content may also be high in acidity and, because of the latter factor, may not be considered sweet. On the other hand, grapes may not be particularly high in sugar but, because of an accompanying low acidity, may be considered sweet. There are also a number of other possible relationships between sugars and acids. The results of this investigation provide a measure of some of the factors that determine quality.

In recent years, much interest has developed in the value of different grape varieties for wine. Ohio probably ranks next to California and New York in the amount of wine made in the United States. Although no effort has been made to prepare wine in this study, the results which are reported should prove useful with respect to the value of different varieties for wine.

The season of 1933 was favorable at Wooster for the development of agreeable flavor in grapes; that of 1934 was less suitable. The sugar content of a given variety of grapes at Wooster probably will average 2 per cent less than in the more favorably located commercial section near Lake Erie. At Wooster, the sugar content of many of the varieties was around 2 per cent higher in 1933 than in 1934. The sugar content at Wooster in the favorable season of 1933 compared well with that for a given variety, such as Concord, in the Lake Section on the basis of the average there over a period of years. The season of 1934 serves well to exemplify the sugar content of grapes grown in parts of Ohio other than in the Lake Section.

METHODS

Three bunches of each of the 120 varieties were picked when ripe enough for eating. The samples were obtained in duplicate each year. They were placed in 1-quart, air-tight cartons and were then placed into storage at —20° C. where they were kept frozen thoroughly until analyzed. This procedure made it possible to conduct the determinations within a short period of time rather than making it necessary to continue the work at intervals over an approximately 2-month period from the earliest to latest ripening varieties. No changes of any consequence seem to have occurred either when the grapes

were frozen or when they were being examined. In fact, probably less error was encountered than if each variety had been examined under variable working conditions on the day it was picked.

The grapes were thawed for one-half day or overnight before pressing. A small hydraulic press was used to extract the juice; the pressure used ranged between 2500 and 5000 pounds. Enough juice was taken from the sample to secure (a) a specific gravity reading and (b) the sugar (total solids) content by means of a refractometer with a scale giving directly the percentage of sugar.

After recording the sugar contents, the juices (in their original containers) were again placed in the low-temperature storage until the sugar determinations were completed on all the varieties. Then the samples were thawed for the acidity and color determinations.

In the acidity work, 25 cubic centimeters of juice were taken and diluted 10 times with water. The dilution was necessary to obtain a good reading when titrating against the juice of the very dark colored varieties. Phenolphthalein was used as the indicator.

At first, Ridgway's color charts were used in an effort to state the colors in standardized terms; however, this did not prove satisfactory. A simple color classification finally was employed. The colors of the natural juices were compared by filling test tubes half full and arranging them in a line with the darkest at one end and the lightest colors at the other. The comparisons were made in a greenhouse in daylight; the tubes of juice samples of the 120 varieties were lined up in test-tube holders on a raised bench. An attempt was made first to consider the various shades of red, then the browns, and, lastly, the clays (gray).

SPECIFIC GRAVITY

Various types of spindles have been commonly used in commercial grape-product manufacture to obtain a measure of the sugar content. Alwood (1) has discussed the comparative accuracy of Oeschle, Balling, Baumé, specific gravity, and Brix spindles. He has reached the conclusion that Brix determinations with a specially made type of spindle are sufficiently accurate for comparative purposes in work on grape juices if an average of the nonsugar solids of the different varieties is allowed in each case, notwithstanding the fact that such nonsugar solids range from 1.5 to 4 per cent in different varieties. Thompson and Whittier (6) take issue with this conclusion. They state that: "Methods employing specific gravity determinations (as by the use of the Brix spindle) as a basis for calculating the total sugars or even the solids, are very questionable on unknown solutions. In order to use such a method on a fruit juice, it is first necessary to accomplish an accurate analysis upon each fruit juice and even upon each variety of the same fruit before a spindle can be used with any degree of accuracy for determining the total sugars." Caldwell (2) concluded: "Brix precision hydrometers, calibrated to 0.1 per cent of sugar at 17.5° C., of the type recommended by Alwood, were used. As the temperatures at which the field readings had to be made were those of an open shed and varied from 6.5 to 32.7° during the work, it was not expected that the corrected readings would give more than approximations of the sugar content as determined by analysis. As soon as the analytical work was under way it became evident that the readings were without much value either for comparison of varieties with one another or for comparing the juices of the

same variety in different years. The nonsugar solids of the varieties studied range from 0.57 to 4.5 per cent, and the amount in a given variety fluctuates very considerably from year to year. The occasional presence of varying amounts of cane sugar in grape juice also contributes to inaccuracy in spindle readings."

In the present work, the specific gravity test immediately preceded the refractometer reading. In general, a comparatively high specific gravity reading accompanied a high sugar content. However, considerable variation occurred, not only in the same variety but between varieties. Two samples, either of the same or different varieties, sometimes showed an identical specific gravity reading but an appreciably different sugar content. In fact, the fluctuation in relation between specific gravity reading and sugar content is large enough to make the former method of questionable value for accurate determinations in work with grape juices, although it unquestionably has usefulness for rapid, economical, and approximate comparative purposes in commercial practice.

SUGAR CONTENT

The refractometer gives a more reliable measure of the sugar content than is provided by the specific gravity readings; hence, subsequent discussion on sugar content is based on the refractometer determinations.

Concord is very widely grown. Table 2 has been arranged for convenient comparison of other varieties with Concord. In grouping, comparatively small differences are not always indicated as well as could be desired. In some cases, the difference between certain varieties in sugar may be 0.9 and yet they are listed in the same group (for example, varieties with 19.0 and 19.9 per cent sugar, respectively). In some other cases where the difference is only 0.1 per cent, the varieties may appear in different groups (for example, varieties with 19.9 and 20.0 per cent sugar, respectively). The grouping, obviously, is an arbitrary one; the actual data are presented in Table 1.

According to the arrangement in Table 2, 20 of the 120 varieties are classified in the same group as Concord, 82 are higher, and 17 are lower in sugar content than Concord. The fact is self-evident that Concord does not rank high among the varieties in sugar content.

In general, the percentage of alcohol obtained in wine making is slightly less than half the sugar content of the grapes used.

As a rule, the varieties with small berries rank higher in sugar content than those with large sized berries.

The fact that Delaware is high in sugar is generally recognized. The Delaware grapes produced in the vicinity of Sandusky on the mainland and on the nearby islands in Lake Erie probably are superior in quality to the Delaware grapes grown elsewhere in the State, or, in fact, in most parts of the country. Berckmans, which is ranked in the same group as Delaware, is supposedly a hybrid of Clinton and Delaware. Wittel No. 10, the third variety in the highest sugar group, originated with Jacob F. Wittel, R. F. D. 7, Peru, Indiana.

Many of the varieties that produce superior wine are small-berried. Moreover, the picking is slow; the yield per acre is low; the vines are adapted only to a much more limited range of growing conditions than Concord; and, with a few exceptions, they are not suitable as table grapes.

TABLE 1.—Specific Gravity, Total Solids (Sugars), and Acidity Determinations on 120 Grape Varieties

Variety	Specific gravity		Total solids (sugars)			Total acidity*		
	1933	1934	1933	1934	Av.	1933	1934	Av.
			Pct.	*Pct.*	*Pct.*	*C. c.*	*C. c.*	*C. c.*
Agawam	1.077	1.070	20.4	18.2	19.3	8.6	8.0	8.3
Amber Queen	1.091	1.085	23.2	20.2	21.7	8.0	9.6	8.8
America	1.059	1.048	17.1	15.1	16.1	18.0	18.4	18.2
Amethyst	1.054	1.060	14.6	16.4	15.5	5.2	7.2	6.2
August Giant	.....	1.077	.....	19.3	19.3	.....	11.6	11.6
Banner	1.070	1.066	19.0	16.6	17.8	6.8	8.0	7.4
Beacon	1.064	.....	17.3	.....	17.3	7.6	.....	7.6
Ben Hur	1.072	1.071	20.0	19.2	19.6	11.6	14.8	13.2
Berckmans	1.094	1.089	24.2	22.8	23.5	18.0	17.6	17.8
Beta	1.087	.....	22.1	.....	22.1	17.6	18.0	17.8
Blondin	1.067	1.070	17.1	18.9	18.0	9.6	9.2	9.4
Brighton	1.086	1.069	22.1	18.6	20.4	4.8	6.0	5.4
Brilliant	1.075	1.067	19.8	19.2	19.5	4.8	5.6	5.2
Brocton	1.088	1.080	24.0	19.1	21.5	6.0	7.6	6.8
Brown's Seedling	1.067	1.065	17.3	15.0	16.2	7.2	8.8	8.0
Caco	1.067	1.072	18.3	18.0	18.2	4.8	5.6	5.2
Campbell Early	1.063	1.053	17.0	17.0	17.0	6.8	7.2	7.0
Captain	1.072	1.070	18.2	17.0	17.6	11.2	12.0	11.6
Captivator	1.076	1.063	20.2	16.6	18.4	7.2	7.6	7.4
Carman	1.071	1.071	20.2	17.0	18.6	10.8	10.6	10.7
Catawba	1.077	1.073	19.8	18.4	19.1	12.4	13.6	13.0
Champaneil	1.066	.....	18.2	.....	18.2	12.4	.....	12.4
Champion	1.065	1.066	16.0	16.0	16.0	8.8	12.4	10.6
Chasselas Rose	1.071	.....	20.1	.....	20.1	5.2	6.4	5.8
Clinton	1.085	1.087	21.3	21.8	21.6	20.4	22.8	21.6
Concord	1.069	1.065	18.2	16.8	17.5	7.2	8.8	8.0
Concord Sport	1.068	1.066	18.6	17.0	17.8	7.2	8.8	8.0
Cottage	1.064	1.064	17.0	16.6	16.8	7.6	9.6	8.6
Cynthiana	.....	1.069	.....	19.0	19.0	.....	16.0	16.0
Dakota	1.081	1.072	24.1	19.0	21.5	16.8	14.8	15.8
Delakins	1.063	1.065	17.0	16.2	16.6	9.6	11.2	10.4
Delaware	1.094	1.092	24.4	23.0	23.7	6.0	7.2	6.6
Delicious	1.074	1.066	19.4	18.2	18.8	6.0	8.4	7.2
Diamond	1.079	1.065	23.5	17.0	20.3	5.6	7.2	6.4
Diana	1.073	1.075	20.3	18.8	19.6	8.0	7.2	7.6
Dracut Amber	1.064	1.060	17.3	16.6	17.0	7.2	10.0	8.6
Dunkirk	1.084	1.080	23.2	20.9	22.1	8.4	10.8	9.6
Dutchess	1.065	1.079	17.4	20.0	18.7	7.6	6.8	7.2
Early Daisy	1.075	1.070	20.0	18.0	19.0	6.8	8.4	7.6
Early Victor	1.062	1.077	17.0	19.6	18.3	12.4	13.6	13.0
Eaton	1.066	1.060	18.2	16.0	17.1	7.6	8.4	8.0
Eclipse	1.082	1.076	21.3	19.6	20.5	9.2	10.0	9.6
Ellen Scott	1.092	1.076	26.0	18.3	22.2	9.6	11.6	10.6
Elvira	.....	1.075	.....	18.9	18.9	.....	9.6	9.6
Empire State	1.072	1.062	19.5	15.6	17.5	6.8	8.4	7.6
Etta	1.051	1.050	18.2	14.8	16.5	10.0	12.8	11.4
Fern Munson	1.080	1.055	22.2	15.8	19.0	10.8	12.0	11.4
Fredonia	1.074	1.037	20.0	14.0	17.0	6.4	8.0	7.2
Gaertner	1.081	1.075	21.1	19.2	20.2	6.4	8.4	7.4
Geyer	.....	1.064	.....	14.0	14.0	.....	7.6	7.6
Goethe	1.069	.....	18.0	.....	18.0	5.6	6.8	6.2
Gold Coin	1.064	1.072	18.2	18.7	18.5	4.8	6.0	5.4
Green's Early	1.081	1.078	20.3	19.9	20.1	6.0	8.0	7.0
Green Mountain	1.093	1.080	25.0	19.6	22.3	6.0	6.4	6.2
Hanover	.....	1.088	22.3	22.4	22.4	6.4	8.4	7.4
Headlight	1.082	.....	21.6	19.4	20.5	6.4	6.4	6.4
Hernito	1.080	1.075	21.3	18.7	20.0	7.6	9.2	8.4
Herbert	1.081	1.080	21.0	20.3	20.7	9.6	10.4	10.0
Hicks	.....	1.067	21.6	17.0	19.3	8.8	9.6	9.2
Hubbard	1.083	1.082	22.2	20.1	21.2	8.0	9.2	8.6

TABLE 1.—Specific Gravity, Total Solids (Sugars), and Acidity Determinations on 120 Grape Varieties—Continued

Variety	Specific gravity		Total solids (sugars)			Total acidity*		
	1933	1934	1933	1934	Av.	1933	1934	Av.
			Pct.	*Pct.*	*Pct.*	*C. c.*	*C. c.*	*C. c.*
Iona	1.085	.....	21.3	.....	21.3	9.2	10.0	9.6
Isabella	1.074	1.065	21.1	16.9	19.0	11.2	10.0	10.6
Ives	1.057	.....	16.2	.....	16.2	10.0	.....	10.0
Jefferson	1.085	.....	21.3	.....	21.3	7.2	.....	7.2
Jessica	1.093	1.075	24.0	20.1	22.1	6.0	6.4	6.2
King	1.060	1.064	16.2	16.3	16.3	9.6	10.0	9.8
King Phillip	1.093	1.075	23.2	20.0	21.6	10.0	8.0	9.0
Lady	1.085	1.082	22.2	20.0	21.1	8.8	8.0	8.4
Lady Washington	1.074	1.091	19.3	24.4	21.9	5.6	7.6	6.6
Lindley	1.076	1.074	21.2	19.5	20.4	6.4	5.6	6.0
Lucile	1.074	1.068	19.1	16.6	17.9	7.6	5.6	6.6
Lukfata	1.068	.....	19.0	.....	19.0	11.6	12.4	12.0
Lutie	1.068	1.079	17.8	20.0	18.9	6.8	10.4	8.6
Mammoth	1.051	1.047	14.4	13.0	13.7	14.4	13.6	14.0
Manito	1.077	1.060	21.3	15.9	18.6	8.8	10.8	9.8
Massasoit	1.075	1.075	19.6	19.2	19.4	6.0	11.2	8.6
Mericadel	1.086	1.073	22.1	19.0	20.6	18.4	18.8	18.6
McPike	1.069	1.066	19.0	17.1	18.1	8.8	11.6	10.2
Miami	.....	1.068	21.0	17.8	19.4	7.6	9.6	8.6
Montefiore	.....	1.070	23.6	17.7	20.7	6.4	7.2	6.8
Moore Early	1.072	1.070	19.9	17.9	18.9	8.0	10.4	9.2
Moyer	.....	.....	18.0	20.4	19.2	5.6	7.6	6.6
Nectar	1.085	1.075	21.3	18.9	20.1	7.2	11.6	9.4
Niagara	1.055	1.074	16.3	18.2	17.3	6.0	5.6	5.8
Ontario	1.081	1.078	22.0	19.4	20.7	7.6	9.6	8.6
Pocklington	1.072	1.072	20.5	21.1	20.8	9.2	6.8	8.0
Portland	1.065	1.088	20.2	20.8	20.5	5.6	7.6	6.6
Red Giant	1.057	1.050	19.3	14.1	16.7	8.0	11.6	9.8
Red Wing	1.068	1.058	17.2	14.9	16.1	11.2	11.6	11.4
Regal	1.075	1.065	19.1	16.9	18.0	12.0	12.0	12.0
Riley	1.074	.....	20.3	.....	20.3	8.0	9.6	8.8
Ripley	1.067	.....	20.2	.....	20.2	7.6	.....	7.6
Rockwood	1.078	1.073	21.0	18.1	19.5	6.8	8.4	7.6
Rommel	1.064	1.068	17.2	17.0	17.1	6.8	8.0	7.4
R. W. Munson	1.076	1.071	20.0	18.1	19.1	10.8	12.0	11.4
Salamander	1.076	1.069	19.9	16.4	18.2	7.2	8.8	8.0
Salem	1.067	1.060	18.0	16.1	17.1	4.8	8.4	6.6
Thompson No. 5	1.081	1.062	19.0	16.0	17.5	10.0	10.4	10.2
Townsend	1.067	.....	17.9	.....	17.9	10.4	.....	10.4
Ulster	1.080	1.086	20.6	21.4	21.0	5.6	8.0	6.8
Union	1.060	.....	15.7	.....	15.7	5.6	.....	5.6
Urbana	1.080	1.078	21.1	19.4	20.3	7.6	8.4	8.0
Vergennes	1.059	.....	16.2	.....	16.2	9.2	.....	9.2
Wapanuka	1.069	1.057	20.2	15.0	17.6	9.6	10.4	10.0
Wayne	1.073	1.072	19.0	18.2	18.6	6.4	6.0	6.2
Wehner	1.046	1.049	12.3	13.1	12.7	20.8	23.2	22.0
Wilder	1.074	1.085	19.0	21.5	20.2	8.4	7.2	7.8
Wittel No. 2	1.076	1.067	20.2	17.2	18.7	9.2	10.8	10.0
Wittel No. 4	1.088	1.072	23.0	17.8	20.4	7.6	10.8	9.2
Wittel No. 10	1.098	1.087	26.0	21.0	23.5	17.6	16.4	17.0
Wittel No. 16	1.084	1.070	21.2	16.8	19.0	11.2	12.0	11.6
Wittel No. 18	1.063	1.064	17.4	17.0	17.2	5.2	6.4	5.8
Wittel No. 20	1.073	1.076	20.9	19.0	20.0	7.6	9.6	8.6
Wittel No. 31	1.081	.....	21.7	.....	21.7	6.4	.....	6.4
Wittel No. 39	1.063	1.055	16.0	14.2	15.6	10.8	12.4	11.6
Wittel No. 42	.....	.....	19.6	.....	19.6	6.8	.....	6.8
Woodruff	1.078	.....	20.4	.....	20.4	9.6	.....	9.6
Worden	1.063	1.062	17.1	17.2	17.2	6.4	8.4	7.4
Wyoming	1.068	1.072	18.1	17.5	17.8	6.4	7.2	6.8
Xenia	1.065	1.071	16.1	18.0	17.1	6.8	8.0	7.4

*In terms of cubic centimeters normal alkali to neutralize 100 c. c. of expressed juice.

The Ellen Scott variety seems well worthy of special comment. It originated with T. V. Munson. The bunches of grapes of this variety have been larger (resembling those of *V. vinifera* as grown in California), and the yield per vine has been higher than has been the case with any of the 120 varieties in the vineyard at Wooster. It may be promising for wine and seems well worthy of test for this purpose. As a table grape, this variety has been practically worthless; a peculiarity is that the seeds "float loose" in the juice inside the skins.

TABLE 2.—Groups of Varieties According to Sugar Content (2-year Average)

Sugar content	Varieties
Pct.	
23.0–23.9	Berckmans, Delaware, Wittel No. 10
22.0–22.9	Beta, Dunkirk, Ellen Scott, Green Mountain (Winchell), Hanover, Jessica
21.0–21.9	Amber Queen, Brocton, Clinton, Dakota, Hubbard, Iona, Jefferson, King Phillip, Lady, Lady Washington, Wittel No. 31
20.0–20.9	Brighton, Chasselas Rose, Diamond, Eclipse, Gaertner, Green's Early, Headlight, Hernito, Herbert, Lindley, Mericadel, Montefiore, Nectar, Ontario, Pocklington, Portland, Riley, Ripley, Ulster, Urbana, Wilder, Wittel No. 4, Wittel No. 20, Woodruff
19.0–19.9	Agawam, August Giant, Ben Hur, Brilliant, Catawba, Cynthiana, Diana, Early Daisy, Fern Munson, Hicks, Isabella, Lukfata, Massasoit, Miami, Moyer, Rockwood, R. W. Munson, Wittel No. 16, Wittel No. 42
18.0–18.9	Blondin, Caco, Captivator, Carman, Champanell, Delicious, Dutchess, Early Victor, Elvira, Goethe, Gold Coin, Lutie, Manito, McPike, Moore Early, Regal, Salamander, Wayne, Wittel No. 2
17.0–17.9	*Concord*, Banner, Beacon, Campbell Early, Captain, Concord Sport, Dracut Amber, Eaton, Empire State, Fredonia, Lucile, Niagara, Rommel, Salem, Thompson No. 5, Townsend, Wapanuka, Wittel No. 18, Worden, Wyoming, Xenia
16.0.16.9	America, Brown's Seedling, Champion, Cottage, Delakins, Etta, Ives*, King, Red Giant, Red Wing, Vergennes
15.0–15.9	Amethyst, Union, Wittel No. 39
14.0–14.9	Geyer
13.0–13.9	Mammoth
12.0–12.9	Wehner

*Vines in poor condition.

The vines at Wooster are trained to the single-trunk four-cane Kniffin system. In the Lake Section in Ohio, the Fan (modified) system is used more extensively than the Kniffin. It is granted that the Fan system is better adapted than the Kniffin for the Catawba variety. The growers in the Lake region have always favored the Fan system (modified) to the Kniffin system. Growers in the Lake Section have claimed that the higher sugar content in their grapes is due in part to the system of training that they are using and in part to the longer, less changeable growing and ripening conditions associated with the influence due to the proximity to the body of water. The sugar content of the grapes at Wooster in 1933 (Kniffin system) compares well with the average over a period of years in the Lake Section (Fan system); the reading of 26 per cent for two of the varieties (Table 1) is as high as may be expected from American-type grapes. It would seem that the higher average sugar content in the Lake Section is due practically entirely to proximity to the large body of water rather than to any influence of system of training.

Hence, because there are certain merits in the Kniffin which are not found in the Fan system (3), it could be used to better advantage throughout Ohio than often has been the custom.

ACIDITY

In Table 3, the varieties are arranged for comparison of the acidity with Concord (the groups are arbitrary, as indicated previously). It will be noticed that 19 of the 120 varieties are grouped with Concord, 51 are more acid, and 49 are less acid than Concord. From the standpoint of number of varieties ranking above and below it, the status of Concord is less unfavorable in acidity than in sugar.

TABLE 3.—Varieties Grouped According to Acidity (2-year Average)

Total acidity*	Varieties
C. c.	
22.0–22.9	Wehner
21.0–21.9	Clinton
20.0–20.9	
19.0–19.9	
18.0–18.9	America, Mericadel
17.0–17.9	Berckmans, Beta, Wittel No. 10
16.0–16.9	Cynthiana
15.0–15.9	Dakota
14.0–14.9	Mammoth
13.0–13.9	Ben Hur, Catawba, Early Victor
12.0–12.9	Champanell, Lukfata, Regal
11.0–11.9	August Giant, Captain, Etta, Fern Munson, Red Wing, R. W. Munson, Wittel No. 16, Wittel No. 39
10.0–10.9	Carman, Champion, Delakins, Ellen Scott, Herbert, Isabella, Ives, McPike, Thompson No. 5, Townsend, Wapanuka, Wittel No. 2
9.0– 9.9	Blondin, Dunkirk, Eclipse, Elvira, Hicks, Iona, King, King Phillip, Manito, Moore Early, Nectar, Red Giant, Wittel No. 4, Woodruff, Vergennes
8.0– 8.9	*Concord*, Agawam, Amber Queen, Brown's Seedling, Concord Sport, Cottage, Dracut Amber, Eaton, Hernito, Hubbard, Lady, Lutie, Massasoit, Miami, Ontario, Pocklington, Riley, Salamander, Urbana, Wittel No. 20
7.0– 7.9	Banner, Beacon, Campbell Early, Captivator, Delicious, Diana, Dutchess, Early Daisy, Empire State, Fredonia, Gaertner, Geyer, Green's Early, Hanover, Jefferson, Ripley, Rockwood, Rommel, Wilder, Worden, Xenia
6.0– 6.9	Amethyst, Brocton, Delaware, Diamond, Goethe, Green Mountain (Winchell), Headlight, Jessica, Lady Washington, Lindley, Lucile, Montefiore, Moyer, Portland, Salem, Ulster, Wayne, Wittel, No. 31, Wittel No. 42, Wyoming
5.0– 5.9	Brighton, Brilliant, Caco, Chasselas Rose, Gold Coin, Niagara, Union, Wittel No. 18

*In terms of cubic centimeters of normal alkali to neutralize 100 c. c. of expressed juice.

The grapes listed with the highest acidity, such as Wehner, Clinton, and those in several of the groups in order of descending acidity, are not desirable for eating out of hand. Some varieties with the lowest acidity, such as Brighton, Caco, and Delaware, are of good eating quality. Probably most people prefer a subacid grape, such as the three previously mentioned; but

others find one such as Herbert, which is slightly higher in acidity than Concord, more to their liking. The higher acidity of Herbert provides a "briskness", or "sprightliness", which is not found in subacid varieties.

For certain kinds of wines, comparatively high acidity in the grapes is desirable; in fact, in some countries, acid (such as citric acid) sometimes is added when making the wine to compensate for deficiency in acidity of the grapes. Further details on acidity are given in the succeeding discussion on the sugar-acid relation.

SUGAR-ACID RELATION

The fact is recognized that quality in grapes does not depend entirely on the sugar-acid relation. Some usefulness for indicator purposes is claimed, however, for the sugar-acid relation. Support for this contention is provided by the work of Caldwell (2) in New Jersey who concluded as follows: "Broadly speaking, the fact that the acid-sugar ratio is as constant as the figures show it to be when the crops were produced under the variety of seasonal conditions encountered at Vineland in 1919-1923 shows conclusively that knowledge as to the ratio for a given variety is of material assistance in indicating its possibilities as a source of beverage juice."

The fact is noteworthy that the Wehner variety ranks highest in acidity and lowest in sugar. It is very low in quality; this is sufficient explanation for the fact that this variety is little known or grown.

It should be understood that improvement in flavor both in unfermented and fermented products may be brought about by blending the juices of different varieties, sometimes to increase acidity and sometimes to decrease it. In this discussion, however, comment is made only on the sugar-acid relation of unblended juice of the different varieties.

Varieties that rank high in both sugar and acid are valuable for wine rather than for eating out of hand; for example, the Clinton variety, which is small-berried, dark colored, low yielding, and a selection from the "wild", is entirely a wine grape. The high acidity of Clinton is a merit, not a fault, in wine making.

The Catawba variety, which is one of America's oldest varieties, ranks high in both sugar and acidity, although lower in both than is the case with Clinton. Catawba probably ranks as the outstanding champagne variety in the United States (champagne is, of course, made by special procedure from a blend of several juices). Catawba when properly matured, as in the long ripening season in the Lake Section near Sandusky, is desirable for eating out of hand. The Isabella variety appeared in 1818, 5 years earlier than Catawba. Concord was not introduced commercially until 1854. Both Isabella and Catawba were introduced when wine making was a major object and table grape purposes of secondary importance.

In the group with high sugar and medium acidity, wine varieties predominate over those for table use. The Iona, in particular, makes a splendid wine. Ontario, a comparatively recent introduction, is rapidly assuming an important place in the wine industry. It is somewhat surprising to the writer that more good table grapes do not appear in this group. Even Moore Early, which is classed here and which has been extensively planted as a table grape to precede Concord in season of ripening, is on the decline in amount of planting, largely because of comparatively low yield; Fredonia seems destined to replace Moore Early.

In the high-sugar and low-acidity group, a number of important wine varieties occur, the most outstanding of which is Delaware. This variety and many others in the group are also excellent for eating out of hand. It has seemed advisable to make four divisions in the high-sugar, low-acidity group (See Page 11). With Diana, for example, which is a wine grape and is ranked in Division (a), both sugar and acid are higher than with Caco which is ranked in Division (d) and has been grown chiefly as a table grape. Delaware, in Division (b), is grouped as similar in acidity but it is considerably higher in sugar than Caco. The sweetness of Caco seems to be due more to its very low acidity than to the fact that its sugar content is slightly higher than that of Concord. Captivator, in Division (c), is thought by many (but not all) who have tasted it to be at least the equal and perhaps superior in taste of any of the varieties in the vineyard at Wooster; hence, in the opinion of many people, the balance between sugar and acidity that occurs in Captivator is a desirable one for table grape purposes. Captivator is slightly higher in sugar and slightly lower in acidity than Concord. On the other hand, it is much lower in sugar and slightly higher in acidity than Delaware but similar in acidity to and lower in sugar than Diana. Some deficiency in hardiness of vine and in appearance of fruit accounts, in part, for the fact that Captivator is not grown more widely.

Grouping of 120 grape varieties according to sugar-acid relation:

1. **High sugar and high acidity**
   - (a) **19.0-23.9 per cent sugar and 15.0-21.9 c. c. acidity:** Beta, Berckmans, Clinton, Cynthiana, Dakota, Mericadel, Wittel No. 10.
   - (b) **18.0-22.9 per cent sugar and 10.0-14.9 c. c. acidity:** August Giant, Ben Hur, Carman, Catawba, Champanell, Early Victor, Ellen Scott, Fern Munson, Herbert, Isabella, Lukfata, McPike, Regal, R. W. Munson, Wittel No. 2, Wittel No. 16.

2. **High sugar and medium acidity**
   - (a) **18.0-22.9 per cent sugar and 9.0-9.9 c. c. acidity:** Blondin, Dunkirk, Eclipse, Elvira, Hicks, Iona, King Phillip, Manito, Moore Early, Nectar, Wittel No. 4, Woodruff.
   - (b) **18.0-21.9 per cent sugar and 8.0-8.9 c. c. acidity:** Agawam, Amber Queen, Hernito, Hubbard, Lady, Lutie, Massasoit, Miami, Ontario, Pocklington, Riley, Salamander, Urbana, Wittel No. 20.

3. **High sugar and low acidity**
   - (a) **19.0-23.9 per cent sugar and 7.0-7.9 c. c. acidity:** Diana, Early Daisy, Gaertner, Green's Early, Hanover, Jefferson, Ripley, Rockwood, Wilder.
   - (b) **19.0-23.9 per cent sugar and 5.0-6.9 c. c. acidity:** Brighton, Brilliant, Brocton, Chasselas Rose, Delaware, Diamond, Green Mountain (Winchell), Headlight, Jessica, Lady Washington, Lindley, Montefiore, Moyer, Portland, Ulster, Wittel No. 31, Wittel No. 42.
   - (c) **18.0-18.9 per cent sugar and 7.0-7.9 per cent acidity:** Captivator Delicious, Dutchess.
   - (d) **18.0-18.9 per cent sugar and 5.0-6.9 per cent acidity:** Caco, Goethe, Gold Coin, Wayne.

4. **Medium sugar and high acidity**
   (a) **17.0-17.9 per cent sugar and 10.0-11.9 c. c. acidity:** Captain, Thompson No. 5, Townsend, Wapanuka.

5. **Medium sugar and medium acidity**
   (a) **17.0-17.9 per cent sugar and 8.0-8.9 c. c. acidity:** *Concord*, Concord Sport, Dracut Amber, Eaton.

6. **Medium sugar and low acidity**
   (a) **17.0-17.9 per cent sugar and 7.0-7.9 c. c. acidity:** Banner, Beacon, Campbell Early, Empire State, Fredonia, Rommel, Worden, Xenia.
   (b) **17.0-17.9 per cent sugar and 5.0-6.9 c. c. acidity:** Lucile, Niagara, Salem, Wittel No. 18, Wyoming.

7. **Low sugar and high acidity**
   (a) **12.0-16.9 per cent sugar and 18.0-22.9 c. c. acidity:** America, Wehner.
   (b) **12.0-16.9 per cent sugar and 10.0-14.9 c. c. acidity:** Champion, Delakins, Etta, Ives, Mammoth, Red Wing, Wittel No. 39.

8. **Low sugar and medium acidity**
   (a) **12.0-16.9 per cent sugar and 9.0-9.9 c. c. acidity:** King, Red Giant, Vergennes.
   (b) **12.0-16.9 per cent sugar and 8.0-8.9 c. c. acidity:** Brown's Seedling, Cottage.

9. **Low sugar and low acidity**
   (a) **12.0-16.9 per cent sugar and 5.0-7.9 c. c. acidity:** Amethyst, Geyer, Union.

With 82 of the 120 varieties higher in sugar than Concord, it is perhaps not proper to rank this variety as medium in sugar content. However, for general comparison purposes it has been both convenient and useful to list Concord in the medium sugar group. It ranks almost exactly midway among the 120 varieties in acidity; that is, 51 varieties rank above it and 49 below it in acidity. Concord, the leading American-type table grape, owes much of its popularity to the fact that it thrives well under a wider range of conditions than are suitable for most other varieties. Due to the extensive planting of Concord, this variety is important in wine making. Concord wine is not high in quality, but, because of the quantity of grapes available, it is comparatively cheap. Furthermore, many blends of wines are made with Concord as the base.

In the medium-sugar, low-acidity group occur some varieties that are important from the table grape standpoint, such as Campbell Early, Fredonia, Niagara, and Worden. A number of the varieties in this group are useful for wine but they provide more volume, or bulk, than superior quality.

The Champion variety, which is classified in the low-sugar, high-acidity group, is notoriously poor in quality. It is deficient in factors that determine pleasant flavor. Furthermore, Champion is often picked immature for early marketing and then it is extremely undesirable in flavor. In fact, it sometimes has been an offender serving to reduce the demand for later grapes even

though they are considerably higher in quality. The low quality of Champion, coming, as it does, early in the grape-marketing season, certainly does not promote a desire for any other grape resembling it in appearance.

The Ives variety, which is ranked in the low-sugar, high-acidity group, frequently commands a premium over Concord for wine making. When the Ives samples were collected in 1933, it was noted that the two vines of it at Wooster were weak; they died in the winter of 1933-1934. It seems likely that the tests in 1933 on Ives may be misleading and that this variety should properly be afforded a higher ranking.

Varieties deficient in both sugar and acidity would seem to possess little merit for any of the usual purposes for which grapes are used.

Not infrequently, a certain variety which was better flavored than another in one year may rank below it the next year. This may be explained, in part, by the fact that many factors may affect the sugar-acid relationship from year to year, not only in the same variety but between varieties. For example, conditions could be favorable for the development of desirable quality in early-ripening varieties; yet soon after they were picked some adverse factor, such as a hailstorm, could occur which would result in comparatively low quality of later ripening varieties.

The work reported here covers only a 2-year period. The results given are in accordance with the facts under the conditions that have prevailed at Wooster in 1933 and 1934. It is readily granted that if information over a longer period of years and over a wider range of conditions had been available for interpretation some changes might properly be made in the status of some of the varieties. However, it would seem to be a fact that the data secured provide not only a measure of quality but, also, an explanation for preferences and dislikes concerning different varieties.

COLOR OF JUICE

The color of juice is important in both unfermented and fermented grape products.

In wines, color distinction is based chiefly on the presence or absence of the skins during fermentation. Red wines are those in which fermentation occurs in the presence of the skins; white wines result from fermentation without the presence of skins or pulp. The widely-grown Concord usually makes a light red wine, but a white wine is made of it by pressing the grapes without mashing them.

The color determinations in this work are based on the natural, untreated juice; hence, the results are different with grape juice which is heated and with wine resulting from fermentation. In 1919, using grapes from the same vineyard that supplied the fruit for this study, Thayer (4, 5) reported on the value of a number of varieties for prepared unfermented grape juice. Explanation is needed for the terms "hot" and "cold" that are used in Table 4. In the one case (hot), the grapes were crushed and heated to 60° C. (149° F.) before pressing; in the other (cold), they were simply crushed and pressed; the juice from both lots was heated to 80° C. (176° F.), filtered, bottled, and sterilized at 75° C. (167° F). Hence, both hot and cold lots were heated. The color determinations that Thayer presented are repeated here to augment those obtained in this work.

TABLE 4.—Color of Juice of Grape Varieties

Natural juice color	Variety	Skin color	Color as prepared grape juice*
Blackish purple	Wittel No. 10	Blue	.....
	Dakota	Blue	.....
	America	Blue	.....
Dark maroon purple†	Cynthiana	Blue	.....
	Captain	Blue	.....
	Ben Hur	Blue	Hot: Purple; dense, dark, reddish purple Cold: Cherry; rather dense, dark cherry
	Beta	Blue	.....
	Champanell	Blue	.....
	Ives	Blue	Hot: Almost black Cold: Dark red, almost black
	Clinton	Blue	.....
	Wittel No. 16	Blue	.....
	Rockwood	Blue	Hot: Deep purple; darker than Concord Cold: Dark cherry; rather dense
Purplish maroon‡	Montefiore	Blue	Hot: Very dark red Cold: Old rose; translucent
	Carman	Blue	.....
	Hernito	Blue	Hot: Dark red; dense, dull Cold: Pale old rose; slightly darker than Concord, translucent
	Isabella	Blue	.....
	Townsend	Blue	.....
	Fern Munson	Blue	.....
Light purplish red	Mericadel	Blue	.....
	King Phillip	Blue	.....
	R. W. Munson	Blue	.....
	Beacon	Blue	.....
	Thompson No. 5	Blue	.....
Brownish red	Campbell Early	Blue	Hot: Purple Cold: Old rose
	Fredonia	Blue	.....
	President	Blue	.....
	Early Victor	Blue	Hot: Purple; color like Worden Cold: Bright red; between raspberry and cherry, almost transparent
	Cottage	Blue	Hot: Purple; same as Concord Cold: Reddish purple
	Wilder	Blue	.....
	Eclipse	Blue	Hot: Violet color; slightly redder than Concord Cold: Dull; salmon pink to brownish yellow
	Manito	Blue	Hot: Dark reddish purple: color of Concord or darker Cold: Dark cherry to maroon; translucent
	Hubbard	Blue	.....
	Herbert	Blue	Hot: Dull raspberry Cold: Old rose; bright, translucent
Very dark brown	Early Daisy	Blue	Hot: Purple; very similar to Concord Cold: Dark purple
	Headlight	Blue	.....
Medium brown	Concord	Blue	Hot: Purple Cold: Bright raspberry; translucent
	Moore Early	Blue	Hot: Purple; very similar to Concord
	Champion	Blue	.....
	Hicks	Blue	.....
	Eaton	Blue	.....
	Nectar	Blue	.....
	King	Blue	Hot: Purple; slightly lighter than Concord Cold: Lighter than Concord
	Brown's Seedling	Blue	.....
	Concord Sport	Blue	.....
	Wayne	Blue	.....
	Hanover	Red	.....
	Lutie	Red	Hot: Salmon Cold: Muddy white
	August Giant	Red	.....
	Dunkirk	Red	.....
	Blondin	White	.....

TABLE 4.—Color of Juice of Grape Varieties—Continued

Natural juice color	Variety	Skin color	Color as prepared grape juice*
Pinkish brown	Dracut Amber	Blue	.....
	Amber Queen	Blue	.....
	Ellen Scott	Blue	.....
	Berckmans	Red	.....
	Wittel No. 39	Red	.....
	Mammoth	Red	.....
	Wittel No. 18	Red	.....
	Wittel No. 20	Red	.....
	Gaertner	Red	Hot: Pale dull salmon Cold: Pale green; almost transparent
	Moyer	Red	Hot: Rich raspberry Cold: Very pale yellow; clear, transparent, like standard commercial Catawba
	Miami	Red	.....
	Jessica	White	Hot: Dirty white Cold: Yellowish brown
	Geyer	White	.....
Light brown	Agawam	Red	Hot: Bright red, like Wyoming "hot" Cold: Light yellow, slightly cloudy
	Massasoit	Red	Hot: Bright red Cold: Cloudy yellow
	Pocklington	White	Hot: Brownish yellow, cloudy Cold: Clear, amber, yellow
	Lady	White	Hot: Brownish yellow
Very light brown	Worden	Blue	Hot: Purple; lighter than Concord, more red Cold: Lilac blue; translucent, lighter than Concord
	Delicious	Blue	.....
	Wittel No. 16	Blue	.....
	Caco	Red	Hot: Reddish salmon Cold: Light, golden brown
	Lindley	Red	Hot: Magenta Cold: Pale yellow, clear
	Lucile	Red	Hot: Pale salmon Cold: Muddy white
	Brighton	Red	Hot: Royal purple
	Delaware	Red	Hot: Color of fruit, slightly dull Cold: Pale yellowish green; translucent, cloudy
	Brilliant	Red	Hot: Water color, almost clear Cold: Reddish salmon
	Urbana	Red	.....
	Banner	Red	.....
	Chasselas Rose	Red	.....
	Goethe	Red	.....
	Catawba	Red	.....
	Union	Red	.....
	Woodruff	Red	.....
	Amethyst	Red	.....
	Wyoming	Red	Hot: Bright, light red Cold: Very pale straw color, cloudy
	Wittel No. 31	Red	.....
	Regal	Red	Hot: Pale salmon Cold: Pale yellow; cloudy, translucent
	Salamander	Red	.....
	Ulster	Red	.....
	Wehner	Red	.....
	Delakins	Red	.....
	Niagara	White	Hot: Yellowish white, cloudy Cold: Yellowish white
	Portland	White	.....
	Gold Coin	White	Hot: Pale yellowish green, clear Cold: Very pale yellowish white with a pearly luster, slightly cloudy
	Green's Early	White	Hot: Dirty white Cold: Dirty white
	Xenia	White	.....
	Lady Washington	White	Hot: Cloudy, yellow Cold: Straw color
	Bell	White	Hot: Pale greenish Cold: Greenish brown
	Wittel No. 4	White	.....
	Green Mountain	White	Hot: Pale straw, cloudy Cold: Clear, water color

TABLE 4.—Color of Juice of Grape Varieties—Concluded

Natural juice color	Variety	Skin color	Color as prepared grape juice*
Clay brown	Salem	Red	Hot: Bright red Cold: Pale, clear, water rose to rose pink
	Rommel	White	Hot: Pearly white, cloudy Cold: Pearly white, slightly clearer than when hot
	Wapanuka	White	Hot: Pale coffee color, cloudy Cold: Pale greenish yellow, slightly cloudy
	Empire State	White	Hot: Light yellowish white Cold: Almost clear, slightly yellow
	Diamond	White	Hot: Yellowish white, cloudy Cold: Pale yellowish green, almost transparent
Clay	Captivator	Red	Hot: Rose colored, somewhat cloudy Cold: Golden yellow, cloudy
	Red Wing	Red	.....
	Diana	Red	.....
	Vergennes	Red	.....
	Red Giant	Red	.....
	Wittel No. 2	Red	.....
	Elvira	White	Hot: Pale, greenish, transparent Cold: Pale, greenish, transparent
	Brocton	White	.....
	Dutchess	White	.....
	Etta	White	.....
	Riley	White	.....
	Ontario	White	.....
	Iona	White	.....
	Jefferson	White	.....

*From Thayer, P. 1919. "Varieties of Grapes for Juice". Ohio Mo. Bull. 8:253-260.
†The purple predominates over the red and the blackish tint is less pronounced than in the first group.
‡The maroon predominates over the purple and a good deal of both is apparent.

The 120 varieties are arranged into 10 color groups, Table 4. The skin color does not, with many varieties, provide good indication of the color of the untreated juice. It is not true that blue grapes give one color of juice, red grapes a second color, and white grapes a third color. In fact, it is often impossible to distinguish between the color of natural, untreated juice from certain red-skinned varieties and certain white ones. In the "medium brown" class of juice, where Concord is listed, the grouping includes blue-, red-, and white-skinned varieties.

Certain blue-skinned varieties contain most of the pigment very closely associated with the skins. This is probably the case with Concord, as its untreated juice contains little red color; but, when Concord berries are heated in preparing grape juice, a purple color results. On the other hand, a number of varieties, particularly those listed in the "blackish purple" and "dark maroon purple" groups show much color in the juice that has not been treated.

There are few, if any, good table grapes in the classes of natural juice listed as "blackish purple", "dark maroon purple", "purplish maroon", or "light purplish red". Here, however, are found a number of varieties that make a splendid red wine. These groups, furthermore, include a number of varieties, such as Clinton, which are useful in improving unfermented grape juice made from Concord and the other more commonly grown varieties. The addition of 10 per cent of Clinton juice increases the color of that of Concord, provides a pleasing tartness (due to the high acidity of Clinton which has been shown previously), and retards fading.

In the groups called "brownish red", "very dark brown", and "medium brown", there are a number of important table grape varieties. Most of the blue-skinned ones are capable of being prepared into an attractive and pleasant unfermented grape juice; but only a few of them will make a high-quality wine.

A number of the varieties in the "very light brown", "clay brown", and "clay" groups will produce a light-colored, clear wine. For the most part, the varieties in these groups do not make attractive, unfermented grape juice, although the flavor may be pleasant.

It should be understood that an experienced wine maker places much confidence in aroma or "smell" when determining the value of an unknown variety for wine. Aroma in the grape berry is due largely to the presence of one or more esters.

Since there has been no effort whatever in this investigation to make wine from the varieties, no direct information can be presented on the shade of color that would result from fermentation of the grapes, either with or without the presence of the skins.

SUMMARY

1. The sugar content, acidity, and color of untreated juice of 120 grape varieties growing in the vineyard at Wooster were determined in 1933 and 1934.

2. For the determinations, fruit was used which had been kept in low-temperature storage at —20° C. Freezing the grapes facilitated the work and probably decreased the chances of error.

3. The refractometer gives a more reliable measure of the sugar content than is provided by specific gravity readings.

4. The evidence is presented in the form of detailed data and by arrangement of the 120 varieties into a number of groups for convenience in comparison with Concord.

5. In sugar content, 20 of the 120 varieties are classified in the same group as Concord, 82 are ranked higher, and 17 are ranked lower. In acidity, 19 of the 120 varieties are grouped with Concord, 51 are more acid, and 49 are lower in acidity.

6. Comments are made in the text to explain the value of, and preferences or dislikes for, certain representative varieties of grapes as determined by the amounts of, and relation between, the sugar and acid contents.

7. Sugar, acidity, and color determinations serve to provide a measure of the quality of grapes for eating out of hand, for prepared unfermented grape juice, and for wine.

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